Demonstration of DC Grid Protection: PROMOTioN WP9 Update

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Purpose

This document is a summary of the questions and answers during the webcast on Wednesday 13th May 2020.

Reference Document:

Presentation slides available: https://www.hvdccentre.com/wp-content/uploads/2020/05/Demonstration-of-DC-Grid-Protection_PROMOTioN-WP9-Updates_13052020.pdf

Recording available at: Part 1 - https://vimeo.com/420651393; Part 2 - https://vimeo.com/420664126

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Questions and Answers

Q1: I see one of the requirements for WP 9 is equipment interoperability. Which standard are you using to achieve this goal? Is the interoperability on the level of communication?

Have you perhaps considered using the IEC 61850 standard for interoperability on the communication side instead of hard wires?

A1: The functional interoperability of HVDC protection IEDs (also known as relays) manufactured by two different project partners is the key interoperability aspect evaluated in the performed tests. In these tests we examine a single vendor protection system, the performance of which is then compared to the multivendor equivalent. Additionally, the successful operation of the HVDC protection IED prototypes with two HVDC circuit breaker topologies is also demonstrated, and a third HVDC circuit breaker topology will be introduced in future testing. By also examining a test case using the replica control and protection panels alongside an HVDC protection IED the functional interoperability of the protection with the converter controls has also been investigated.

Communication between different hardware protection IEDs has been achieved using physical copper wiring. The academic IED currently has no industrial grade communication protocol implemented. This work is ongoing. For this demonstration we are not planning to use a communication protocol. It should be noted that the only communication shown here is between protection IEDs around the same busbar, and therefore the communication requirements may not be challenging relative to longer distance communication. The other part of WP9 that SuperGrid Institute are undertaking is investigating IEC 61850 for HVDC protection, however, communications defined by the current version of IEC 61850 are likely to be too slow for the speeds of operation required for partially and fully selective HVDC protection schemes. For non-selective schemes – which operate in less stringent time scales – are expected to be able to use IEC 61850. This will be examined in a future public demonstration!

Q2: Are the detection functions limited to the ones mention in slide 19? Is it possible to include more algorithms in the IED ?

A2: It is possible to implement a range of algorithms on either IED. For the academic IED prototype, the design (HW+SW) is available for download under GPL license and you can add your own algorithms. Within the PROMOTioN project we have examined a range of protection algorithms, the outcomes of which can be found in WP4 deliverables (D4.1, D4.2). In the WP9 work (part of which was presented today), the aim was not to compare protection algorithms but to show IED performance in a realistic manner. A suitable algorithm for each case study was therefore chosen for use in the presented results – for the academic protection IED based on either dv/dt or local travelling wave based (travelling wave extraction) and for the industrial protection IED based on dv/dt, di/dt and voltage level.

Q3: Slide #23; Transformers are illustrated as Star-Delta, is that correct? For close HV/LV voltages Auto Transformer would be more correct.

A3: Yes the transformer representation is correct, auto transformer with single winding is not usually used.

Q4: We have any specific class need for CT & VT for DC relay IED. Could you let me know the type and class of CT & VT used

A4: Usually the DC CT/VT are optical they usually don't have class similar to AC CT/VT. For the testing the CT and VT have not been explicitly modelled, voltage and current signals are taken directly from the measurement points. After discussion with instrument transformer experts, we understand that high bandwidth VTs and CTs, although certainly not standard, are available and could be used in such a project. In this respect, testing without representation of the CT and VT is not expected to significantly impact the accuracy of the results.

Q5: For the key performance indicator, why the security against non-fault situation for avoiding mal-operation was not included?

A5: In our testing we evaluate faults along all cables on the network, and certainly do evaluate the dependability as well as the security of the overall protection system. The dependability can be considered an indicator of the protection IED performance, whereas security is more of a measure of overall protection system performance (overall coordination of the protection system and not just a measure of the performance of a particular IED). Given that the results presented in this webinar were only indicating the protection IED performance, only the dependability was shown. We will certainly be publishing results from the overall system testing including the security. Sorry for not explaining this in the slides and omitting the description of security, which will be used as an indicator.

Q6: It appears that the decentralised protection is being investigated, i.e., IED for line, IED for busbar and perhaps IEDs for Main circuit equipment like transformer, etc.?

What was the rationale behind the selection of decentralised protection over centralised protection?

As long as DC line is concerned, decentralised protection makes sense. DC bus protection - i am struggling to understand decentralised protection

A6: The HVDC protection IEDs were designed to work as a centralised system (e.g. one device per bus or substation) as a default – covering three lines and a bus, as this was the initial design brief. However, if the system is to be inter-operable with multi-vendor, then a de-centralised approach is required. Each physical protection IED consists of several functional units allowing simultaneous protection of three network locations (each protecting both positive and negative poles). Using these functional units in different network locations and different functions has allowed us to examine a wider range of case studies. The main focus of the presented results is line protection, for which it is quite clear that fast and discrete protection IEDs have significant benefits.

The case for several protection IEDs communicating in order to coordinate busbar protection is indeed less clear. This isn't a case study that we have presented in our testing, and the discrete protection IEDs (one at each cable end – could be termed 'distributed') are presented for use for primary protection and for providing functionality to detect a circuit breaker failure (which is only evaluated by the IED at the failed circuit breaker).

The question of decentralised or centralised protection should be considered from a functional point of view. Depending on the protection strategy, for instance, the selective strategy requires fast operation, so algorithms that don't require communication are required for primary protection. In the case of the non-selective approach, there is no critical requirement for fast operation and there is time for communication during some parts of the protection sequence, so a centralised solution may be possible for some of the functions required in the strategy, such as recovery of the HVDC system.

Q6: The IED's perform relatively fast in microseconds, although KTH is three times quicker?
As the two IDE have different responses due to hardware implementation and not due to the protection algorithm, which are the key attributes to define the bar in your tests?

A6: The academic IED has no hardware or software redundancy which may partially explain the difference. The algorithms implemented on each are also slightly different, so they have both different H/W and S/W in this case.

Q7: Does interface transformer has any effect on system performance. If any, please suggest how to overcome it in real-time simulation.

A7: We have not faced any issues during cross validation of the converter models between the PSCAD and RSCAD platforms. If you are more interested please have a look in the following link: https://www.hvdccentre.com/wp-content/uploads/2019/12/The-National-HVDC-Center-Project-Report-I-MMC-Modelling.pdf. By selecting the interface transformer to represent a transformer in the system the impedance is sufficient to allow for the change in time step without introducing spurious capacitance.

Q8: Have you considered identical requirements in each IDE to observe interoperability? And also, have you considered to create protection zones e.g. in meshed dc grids?

A8: Although the protection IEDs have been developed to the same high level functional requirements, the particular implementations are quite different, resulting in some difference in the response (as observed in the results presented in the webinar). The tests demonstrate functional interoperability between the protection IEDs (i.e. they would be expected to work together in the same system), although, as highlighted, there are no advanced communications between the IEDs, which otherwise might lead to interoperability problems.

We do work with protection zones, although not necessarily exactly defined in the same way as in AC, and not all options have been tested (yet). In WP4 of PROMOTioN we provide a comparison of partially selective and fully selective protection strategies; in a partially selective protection strategy multiple cables and busbars could be a protection zone, whereas in a fully selective protection strategy the protection zones are typically a single cable (or line). More information can be found in PROMOTioN deliverable D4.2 on the project website.

Q9: In the models Habib described, are the DCCBs modelled in a small-time subsystem with the use of GTFPGA?

A9: Yes, the DCCB are modelled in the small time step but not on a GTFPGA. We only use GTFPGA units for cable modelling in the presented system configuration.